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THE NATIONAL MARINE FISHERIES SERVICE SHRIMP RESEARCH PROGRAM IN THE GULF OF MEXICO*

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The Fishery Conservation and Management Act of 1976 extended United States jurisdiction from the coastline out to 200 miles and provided authority to manage coastal fishery resources within this zone. Conservation and management of the fishery resources as defined by the Act are based on the best scientific information available. In this paper, the status of the scientific information for United States shrimp management in the Gulf of Mexico is reviewed and evaluated. The current Shrimp Research Program is based upon management needs and is described in terms of goals, objectives and the current program. The program is aimed at documenting the geographical boundaries of the shrimp resources, developing surplus production models, developing models which predict potential yield under various levels of fishing, and developing a quantitative model which will estimate current surplus production. Extensive mark and recapture experiments are being conducted in the western portion of the Gulf of Mexico on both white and brown shrimp to obtain information on growth, mortality and migration. Experimental results on growth and migration are described.

INTRODUCTION

The shrimp fishery in the southeastern United States is the most valuable fishery in the country. In 1977, the Gulf and Atlantic coastal states produced 283 million pounds (128, 366 t) of whole shrimp valued at over 321 million dollars. Historically, the Gulf of Mexico has been the major production area for shrimp in the United States and accounts for approximately 80 % of the total value of shrimp landed in the United States. Shrimp production in the area has fluctuated from 134 million pounds (60,781 t) in 1961 to 283 million pounds (128,366 t) in 1977. The predominant species in the Gulf of Mexico are brown shrimp *(Penaeus aztecus)* accounting for over 53 % of total production, white shrimp *(P. setiferus)* accounting for about 26 %, and the pink shrimp *(P. duorarum)* accounting for 15 % of the total production.

Major emphasis on shrimp research was initiated in the late 1950s by the Gulf coastal states and Galveston Laboratory of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) in an exploration of the shrimp resources and definition of basic biological parameters (Temple, 1973; Caillouet & Baxter, 1973). Since that time, the Gulf

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states have continued a strong research role in providing scientific information for management of the shrimp resources. Each state was funded by its respective legislator and undertook programs which provided appropriate information for management. The Federal Government provided biological, catch and fishing effort, and some economic information to the Gulf states. In the early 1960s, intensive surveys by the Bureau of Commercial Fisheries throughout the Gulf of Mexico Pravided basic information on the biology, spawning cycle, maturation, growth and life history of the major shrimp stocks. These findings were summarized by Linder and Cook (1970), Cook and Lindner (1970) and Costello and Allen (1970). In the late 1960s, the Bureau of Commercial Fisheries significantly decreased its emphasis on shrimp research.

In 1976, the United States Congress enacted a bill which extended United States jurisdiction from the edge of state territorial waters offshore to 200 miles and created regional management councils which have the responsibility for developing management plans for all of the United States coastal ocean resources. As a result of this action, emphasis was again placed on providing scientific information for the management of the shrimp resources. This accelerated activity was exemplified by the role of the National Marine Fisheries Service (NMFS) Southeast Fisheries Center's Galveston Laboratory in expansion of shrimp research to provide basic scientific information for management to the appropriate management entities.

This paper summarizes the expanded shrimp research programs presently underway at the Galveston Laboratory and describes their objectives, activities and some of the results obtained during 1977 and 1978.

BACKGROUND

The fishery

The distribution and relative abundance of white, brown and pink shrimp have been described by Osborn *et al.* (1969) and are depicted in Figs. 1-3. The brown shrimp population is distributed throughout the northern and western Gulf of Mexico with the center of abundance off Texas. The number of stocks included and their boundaries have not as yet been documented. White and pink shrimp are are also distributed throughout the northern half of the Gulf with the center of abundance of white shrimp off Louisiana and that of pink shrimp off southern Florida with highest concentrations around the Dry Tortugas area. White shrimp are believed to have a continuous distribution throughout the northern half of the Gulf and into Mexico. Lindner and Anderson (1956) described the results of tagging studies which clearly indicated white shrimp moved across the United States-Mexican border. There appear to be two separate stocks of pink shrimp, one on the Campeche Bank off Mexico and the other off south Florida on the Tortugas and Sanibel grounds.

Description of tagging techniques

Shrimp stock assessment has been based largely on information obtained from tagging studies. Shrimp probably were first tagged in the Gulf of Mexico in the mid-1930s (Lindner & Anderson, 1956) using Petersen disk tags. Since that time, many investigators have used an assortment of different tags and techniques to obtain various information on growth, mortality and movement. Neal (1969) reviewed the marks and marking procedures used up to that time. It was recognized in the 1950s that the Petersen disk tag was not completely suitable for these studies and as early as 1955, Menzel (1955) successfully marked white shrimp by injection of a solution of fast green biological stain. Costello (1959), and Costello and Allen (1962) perfected the use of biological stains for penaeid shrimp and evaluated the effectiveness of these stains and stain injection techniques. This stain injection technique was later used in the Gulf area by Klima (1964), Allen and Costello (1966), Knight and Berry (1967), and Klima (1974). The stain injection technique was severely limited because only groups of shrimp and not individuals could be identified. As a result, the number of marks as well as the data derived from these studies were limited. This led to the use of fluorescent pigments (Klima, 1965) and PVC internal tags (Neal, 1969); both used secondary marks to permit identifying individuals or groups. Welker *et al.* (1975) compared modified Petersen disk tags (i.e., 6 mm in diameter compared to 10 mm in diameter of previous Petersen tags) and biological stains used with internal tags as marks for shrimp. In conclusion, they found no significant difference between recovery rates or growth rates using either tag. However, there appeared to be small non-significant differences in the growth rates in that the shrimp marked with biological stains had a faster growth rate.

The next stage in the evolution of tags was the development of the ribbon tag by Marullo *et al.* (1976). The ribbon tag was developed and tested to a stage where it could be employed by the NMFS in their ongoing investigations. It has been modified slightly from that in the paper described by Marullo *et al.* (1976): the tag is now tapered at the end attached to the needle so that it is easy to insert between the muscular tissues of the shrimp. An Aureomycin mixture is routinely used prior to application to the shrimp to retard infection and secondary bacterial growth. Tags 0.004 in (0.1 mm) in thickness are used to tag juvenile shrimp 50-100 mm in total length but for larger shrimp a thicker 0.006 in (0.15 mm) tag is employed.

Present tagging procedures and methods have been described by Neal (1969) and Emiliani (1971). To protect tagged shrimp during release from predation on the sea floor, Emiliani developed a release canister. Tagged animals are placed in an expendable canister and released overboard while the vessel is underway. The canister drops to the bottom and in ten minutes it opens and the tagged shrimp are released. This greatly reduced mortality by predation at the release site and is a standard technique presently used today.

To insure maximum recovery of tagged shrimp, an incentive system, in one form or another, had been used throughout the Gulf of Mexico. In the past of US$0.50 to $5.00 have been offered for recovered shrimp. On the average, recovery of a tagged shrimp was worth $2.00 to the finder throughout this region for many years. With the intiation of massive tagging programs more than the usual $2.00 incentive was necessary since some shrimp fishermen have stated it is not worth their time to return shrimp for only $2.00. Conversely, many fishermen return shrimp without monetary reward. To increase the return of recaptured shrimp, a fishing contest was estableshed in which awards ranging from $50.00 to $500.00 are paid for recovered shrimp. Fishing contests are run every 45 days during major recovery periods, with four winners for each contest awarded first, second, third, and fourth prizes of $500, $200, S100 and $50, respectively. Winning numbers are preselected by computer at the time of release by a priority system. If the first priority tag selected is not recovered then the second priority is selected and so on until four winners are identified. This tagging incentive system was established for all 1977-78 tag recoveries in the studies which are described in this paper. Tagged shrimp were returned to port agents located in the major ports. These agents normally collect catch and fishing effort statistics, but also handle the recovery of tagged shrimp and have a major responsibility of obtaining and verifying pertinent information on the area and date recaptured.

Biological data base

Wise (1976) indicated that the shrimp fisheries of the Gulf of Mexico are near maximum utilization. Lindner (1965) noted and Wise (1976) concurred, that an increase in shrimp yield could be realized by increasing the average size of shrimp harvested. These authors utilized information presently available; however, they recognized that the present data did not allow proper quantification of the shrimp population in the Gulf of Mexico.

Christmas and Etzold (1977) reviewed the available fishery data and summarized information on growth, mortality and weight/length relationships. The growth information presently available is for few specific localities and seasons and may not be applicable throughout the range of the species and/or stock. Lindner and Anderson (1956) analyzed tagging information obtained in the 1930s to estimate growth; however, it is felt by many investigators that the large Petersen disk tags used by these scientists to mark shrimp may have curtailed or decreased growth rates. Therefore, the estimates on white shrimp presented by Lindner and Anderson (1956) may be underestimates. Growth information summarized by Klima (1964 and 1974) was based on white shrimp marked with biological stains and identified by size groups rather than individuals. The growth model developed was based on average sizes and may not provide information as accurate as that obtained from individuals tagged with numbered tags from which individual growth can be estimated. Parrack (1978) modelled brown shrimp growth, utilizing data from shrimp tagged with small Petersen disk tags, in which growth of individuals was recorded. He summarized the results of tagging experiments from 1968 through 1974 utilizing recoveries of 5,100 individuals, and compared his growth model with those developed by Chavez (1973) for the brown shrimp stocks off Mexico and by McCoy (1972) for brown shrimp stocks off North Carolina. Growth estimates for pink shrimp off North Carolina have been made by McCoy (1972) using shrimp marked with biological stains. Iverson and Jones (1961) Kutkuhn (1966) and Berry (1967) estimated pink shrimp growth for south Florida; Kutkuhn and Berry used biological stains and Iverson and Jones used Petersen disk tags.

Available mortality estimates for brown and white shrimp are limited to a few locations and seasons. If the estimates represent the actual mortalities for the stocks concerned, then each stock may be subjected to extremely different rates of exploitation and to vastly different rates of natural mortality. However, one must question whether the lack of consistency among these authors in estimates of mortality is real or an artifact due to differences in shrimp marking procedures and techniques in estimating mortality. A prime example of the variation in mortality rates is exhibited in the available estimates for weekly instantaneous total mortality (Z) for pink shrimp, which range from 0.11 (Berry, 1969) to 1.41 (Kutkuhn, 1966). Variability and lack of confirmation in estimates of growth and mortality do not provide a good information base required to develop relatively accurate yield models.

Recruitment, survival and growth of white and brown shrimp have been shown to be related to environmental conditions in the estuary during the juvenile and sub-adult phases of the shrimp's life history by St. Amant (1962), Barrett and Gillespie (1975), and Gaidry and White (1973). These authors and other scientists along the Gulf Coast believe that environmental conditions do affect recruitment of shrimp stocks in the estuarine systems. At this time, however, there is no clear understanding of the degree of variation in growth or mortality between seasons, areas and years.

Recognizing the problems associated with the dynamics of the penaeid shrimp stocks in the Gulf of Mexico, Christmas and Etzold (1977) identified four high priority biological research objectives to be accomplished for shrimp management:

1) to develop data on natural mortality rate, age and growth rates;
2) to delineate the offshore spawning grounds of commercial shrimp, and to determine the recruitment patterns for larvae and post-larval shrimp.

3) to determine those commercial landings not reported and the accuracy and precision of data collection techniques, and
4) to determine yield relationships including MSY.

The Gulf of Mexico Fishery Management Council, which has responsibility for developing fishery management plans for all fisheries in the Gulf of Mexico off the United States, concurred with Christmas's and Etzold's (1977) recommendations regarding the high priority research areas.

They further indicated that research should be undertaken to identify the boundaries ot brown and white shrimp stocks which overlap in the United States and Mexico, and estimates should be obtained on growth, mortality and yield for these 'trans-boundary' stocks.

In summary, the information required for management of the shrimp resources of the Gulf Mexico is wanting and specific information needs to be developed on growth and mortality for the major stocks.

PRESENT RESEARCH PROGRAM

The goal of the present shrimp research program is to improve the quality of scientific information provided for the Regional Fishery Management Councils for management of United States shrimp resources. It is anticipated that the following four major steps will be required.

1. Document the geographical extent of the shrimp resources.
2. Develop a surplus production model.
3. Develop a model that predicts the potential yield under various fishing strategies.
4. Develop a quantitative model that estimates current surplus production.

The first step will be to document the geographical boundaries of each stock. Specifically, the geographical origin or genetic makeup of individuals in the stock are of little interest; however, the spatial limits occupied by the exploited population are required.

The second step, the catch and effort model, will be developed from catch and effort data to derive estimates of the surplus production. Application of this approach to allow for the unique biology of shallow-water shrimp could be a long-term ongoing project. It is recognised that this type of approach appears straightforward and simple; theoretically, it is not and may not be directly applicable to the shrimp fisheries at all. As a management tool, this approach may not be the most straightforward or realistic for shrimp stocks that undergo drastic seasonal changes in abundance (Geibel & Heimann, 1976). However, as a first approximation, it can provide useful information.

The third step will develop an analytical model to predict the potential yield under different harvesting regimes. This model is commonly referred to as a yield-per-recruit model as described by Beverton and Holt (1957). It is planned to utilize the approach Paulik and Bayliff (1967) modified to account for age-season natural mortality and growth variable exploitation patterns and other factors specific to shrimp stocks in the Gulf of Mexico. It is believed this model, if properly constructed, can be used as a guide to manage the exploitation of shrimp stocks and to maximize the yield from these stocks. This model, however, cannot estimate the magnitude of the yield nor be used to derive a fishing strategy that will guarantee to sustain a stock size that will continue to produce the maximum yield.

The fourth step will overcome shortcomings of the first two steps in that current estimates of stock size will be incorporated in a model to provide accurate estimates of surplus production. This model will require accurate input data in terms of natural mortality, growth and current estimates of stock size. The major problem will be estimation of current stock sizes. Cohort analysis will be applied to age-catch data to estimate past stock sizes and fishing mortalities, then a history of recruitment abundances and fishing mortalities can be derived. At this point, the dynamic biological system for the resource is quantified. Catch quotas can be set with known results, and the impact of any management regime and environmental circumstances can be defined.

There is a need for improved estimates of growth and mortality because yield models are dependent on accurate estimates of these parameters. It has been previously shown that the present information on growth and mortality is limited, and in conclusion, there are unsolved questions concerning variation in growth in relation to: 1) geographical area; 2) season, and 3) between years. Information is lacking on natural mortality and variations associated with age, area, and season.

The objectives for the shrimp research program undertaken from the Galveston Laboratory in the first year of study are:

1) to define the growth of juvenile white and brown shrimp cohorts from a single estuary;
2) to determine juvenile shrimp migration routes, and
3) to estimate mortality of adult brown and white shrimp associated with a specific estuary.

The objectives for the second year are identical except to expand the program to obtain information on the trans-boundary brown shrimp stocks which occur from Corpus Christi, Texas to Tampico, Mexico.

Documentation of geographical extent of the shrimp resources

Catch and effort information was used to document the geographical boundaries of major stocks within the Gulf of Mexico, and this information (Figs. 1-3) indicates a continuum over broad geographical areas which cannot be used to define isolated stocks. Therefore, the best approach to solve this problem will be to examine the distribution of recoveries of tagged shrimp. Tagging has been conducted in many areas of the Gulf of Mexico; however, the data on recoveries have not been adequately summarized to describe the geographical boundaries of the major stocks. Therefore, the current tagging program (as described later) will provide, along with historical tagging data, specific information on shrimp stock boundaries in the western Gulf of Mexico from New Orleans westward to Tampico, Mexico.

Surplus production model

Kutkuhn (1962) described the current Gulf of Mexico shrimp statistical survey initiated in 1956. Outputs from this survey are annual and monthly shrimp landing and effort statistics which are used as input to the catch and effort model. Standardized fishing effort by species is currently being determined. In the northern Gulf of Mexico vessels catch either brown or white shrimp or both on a given trip. The published landing statistics do not distinguish fishing effort by species. As a result, specifically directed effort on each species is presently not available from pubished reports. However, catch and fishing effort information has been recorded from interviews of fishermen and is being examined and analyzed by individual trips. Total fishing effort by species can be estimated by examining individual trip slips from interview dates and allocating effort by species to the non-interview data.

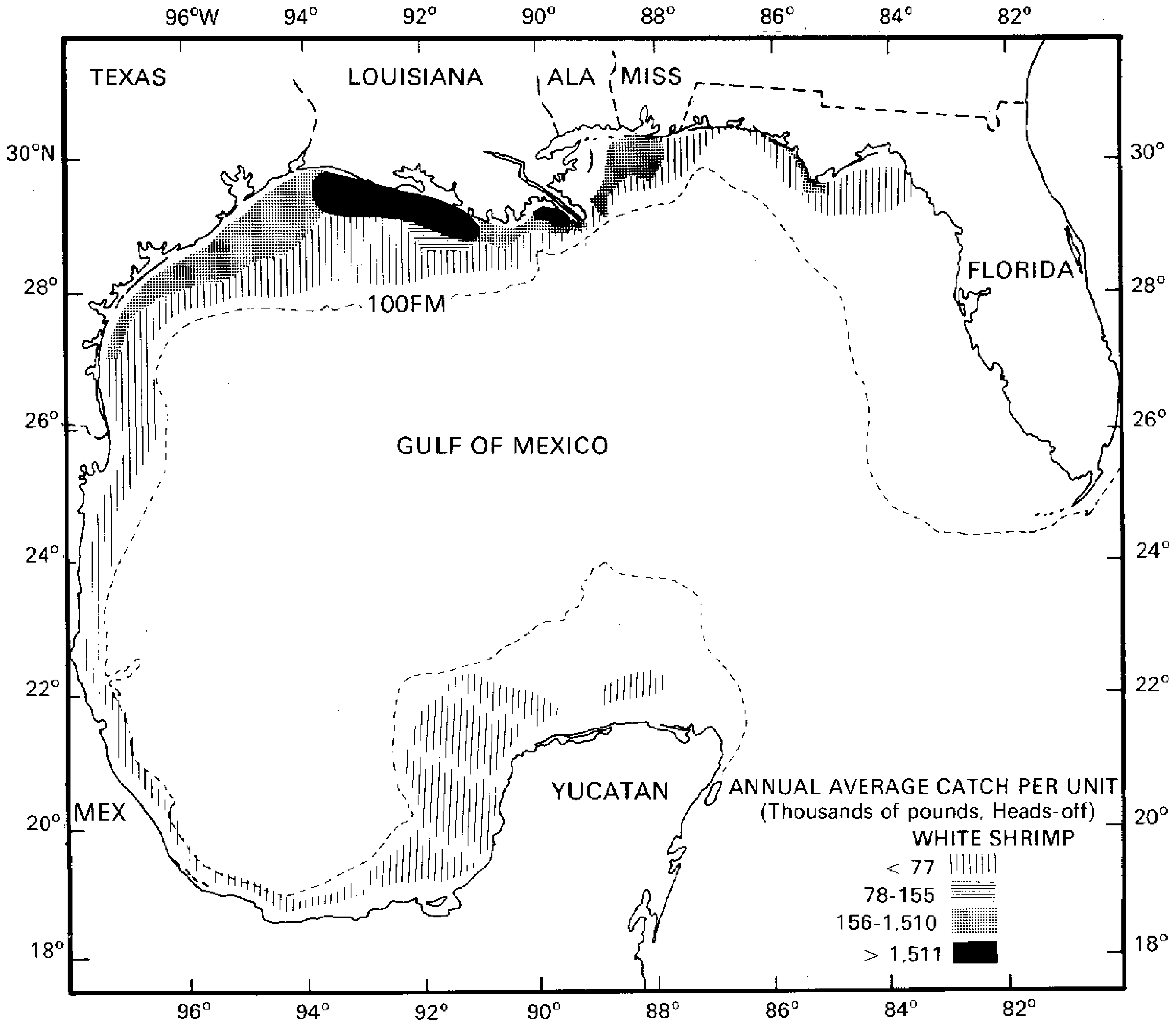

Fig. 1. Distribution of catch per unit (thousands of pounds) of white shrimp in the Gulf of Mexico.

The next major undertaking is to examine temporal trends in vessel characteristics. Fishing gear on shrimp trawlers has undergone significant changes in recent years (Captiva, 1966, 1970), primarily in terms of increased size and power. Juhl (1966) and Klima and Ford (1970) described the trends in fishing gear and tactics employed by the Gulf of Mexico shrimp fleet. These studies highlighted the apparent change in fishing effort during the 1960s. Trawls employed in the 1960s averaged around 40 to 50 foot (12-15 m) head-rope length, whereas at the present time double-rigged boats are fishing with 60 to 70 foot (18-21 m) nets. Many fishing vessels in the Gulf of Mexico and along the eastern seaboard have been converted from double-rig trawlers to twin-trawlers; namely, four nets fished concurrently. It is planned to undertake a study to evaluate the trends in fishing effort and to standardize it. This analysis will encompass examination of vessel size, horsepower, and size and type of fishing gear, from 1960 to the present.

Utilizing catch and effort statistics which have been collected for the past twenty years throughout the Gulf of Mexico from all the major fisheries, a logistic model was developed by Klima and Parrack (1978). They combined the shallow-water shrimp species data from

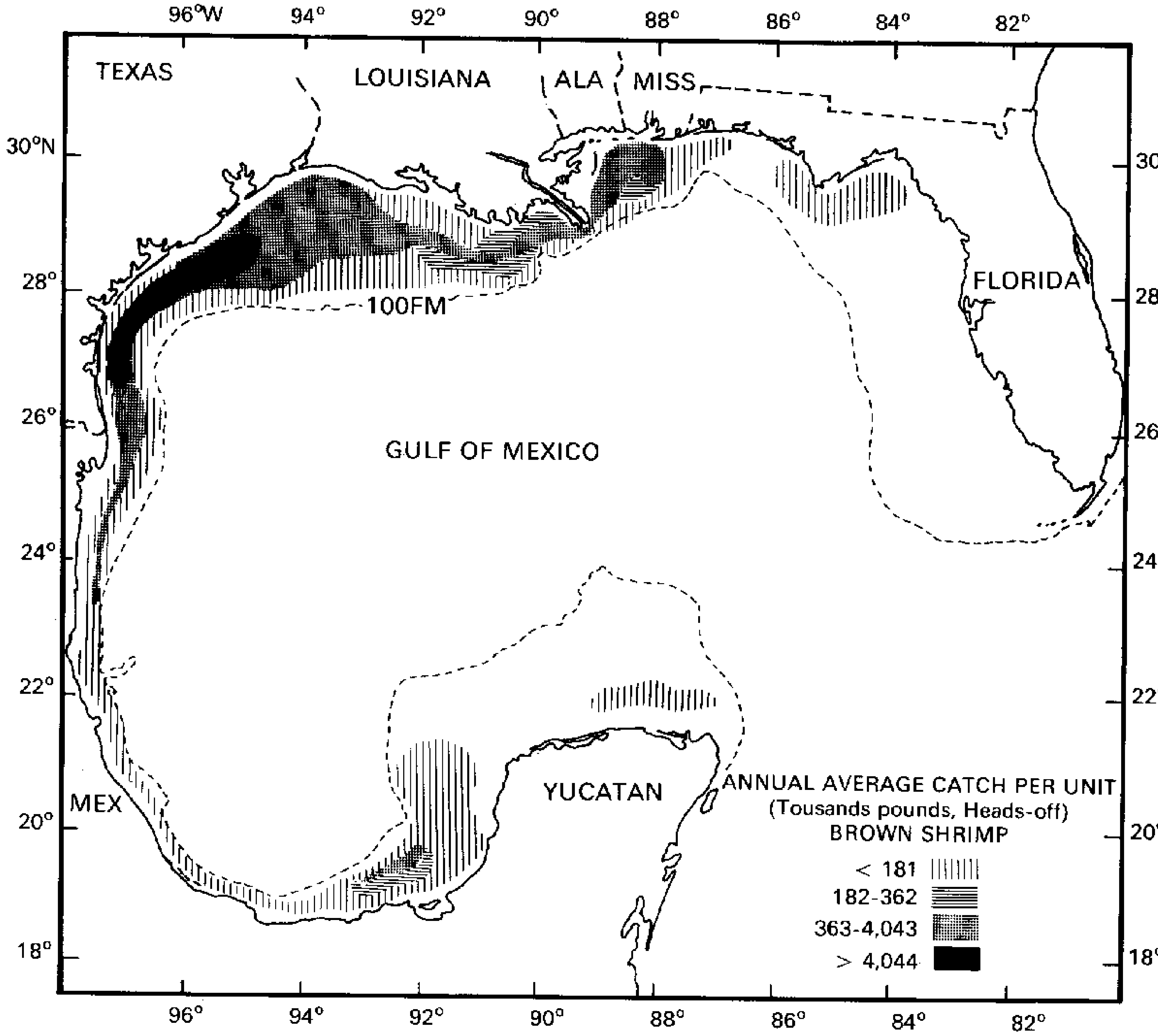

Fig. 2. Distribution of catch per unit (thousands of pounds) of brown shrimp in the Gulf of Mexico.

1956-76 for the Gulf of Mexico since they could not compute species directed effort. The model is described as:

$$L = f\,(a + bf)$$

where,

a = 0.45528, equation constant

b = $-0.9387039622 \times 10^{-6}$, equation constant

f = days fished

L = landings

This model predicts an equilibrium landings-effort relation with a maximum value at 55,000 t tail weight with 225,000 days fished. Parrack (pers. comm.) estimated a steady state condition for the combined shallow water shrimp fisheries in the northeast Atlantic to be modelled by the equation $L = f(4.397764236 - 0.000637235\,f)$. He estimates that the model maximizes equilibrium landings at about 7,600 t tail weight with fishing intensity at about 3,500 operating trawls (Fig. 4). In 1971, almost 9,000 t of tails were produced in this fishery and subsequent landings indicate the resource is being fully utilized.

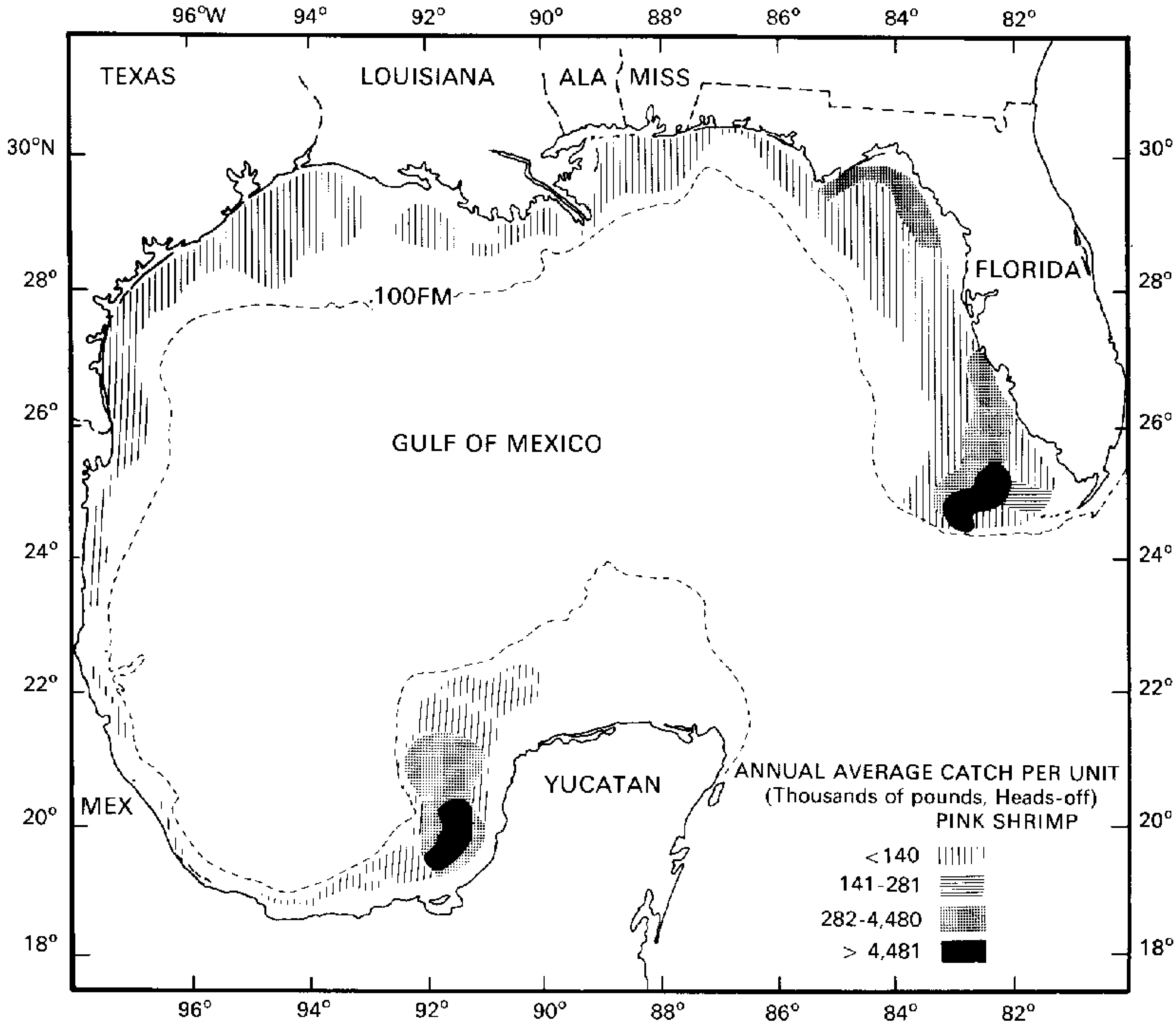

Fig. 3. Distribution of catch per unit (thousands of pounds) of pink shrimp in the Gulf of Mexico.

Model inputs - growth, mortality and stock boundaries

White shrimp

Information provided by mark and recapture studies will provide the major input for the shrimp yield-per-recruit models. With the concurrence of the Gulf of Mexico Fishery Management Council, a tagging study was undertaken in Caillou lake, Louisiana by the Galveston Laboratory in cooperation with the Louisiana Department of Fisheries and Wildlife and Louisiana State University Sea Grant Office. Juvenile white shrimp were tagged and released each month from July to November 1977, the period during which they are normally found in the Louisiana estuarine systems. The objectives of the study were:

1) to measure seasonal growth and migration patterns, and
2) to determine the distribution from the estuarine system to the offshore stocks.

Over 36,000 white shrimp were tagged and released from July through October in this estuarine area. Concurrently, 8,338 white shrimp were tagged and released offshore from this estuary from August through December. As can be seen from Table 1, approximately

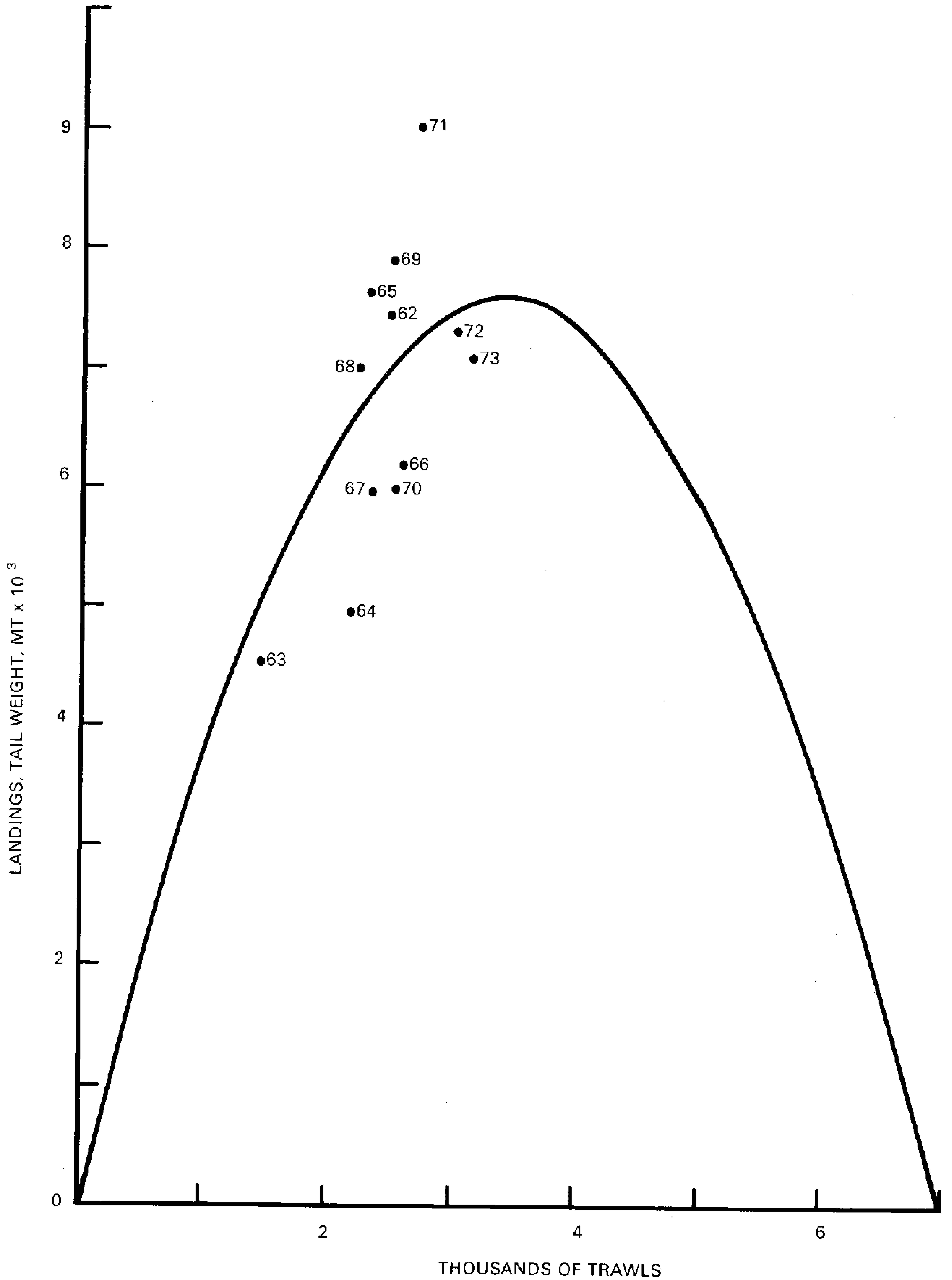

Fig. 4. Relation between fishing effort and landings of shallow water shrimp in the northwest Atlantic Ocean.

Table 1. *Number of tagged white shrimp released in Louisiana waters from July to December 1977 and number and percentage recovered.*

Location	No. released	Recovered	
		No.	%
Inshore	36,639	3,807	10.4
Offshore	8,336	383	4.6
Total	44,975	4,190	9.3

9.3 % of those released were recovered from July through April 1978. This recovery rate is high in comparison to previous mark and recapture experiments conducted in the Gulf of Mexico (Clark *et al.*, 1974). Although there was intensive fishing pressure in the study area, it is believed that one of the factors contributing to the high recovery rate was the new monetary incentive system for the return of recaptured tagged individuals.

The generalized movement of tagged shrimp from the Caillou Lake area is depicted in Fig. 5. Most of the shrimp migrated westward although a small contingent did move eastward, as expected. Recovery data showed an unexpected movement out of the estuary to the offshore area and then back into other estuarine areas. In 71 days one tagged shrimp migrated from Caillou Lake into Galveston Bay, a distance of 220 nautical miles (408 km). Several shrimp tagged in the estuary moved offshore and then migrated to the upper reaches of Vermilion Bay, Louisiana. Another unexpected development was the movement inland of some of the marked shrimp. We believe that part of this was attributed to the fact that it was possible to tag and release extremely small shrimp (50 mm total length). Prior to this study, the smallest marked shrimp released in the Gulf of Mexico were usually larger than 80 mm total length (Clark *et al.*, 1974). Lindner and Anderson (1956) depicted offshore movements similar to those observed in this study. However, they did not show movement of shrimp from Louisiana into Texas waters. Most of the tagged shrimp were recovered in close proximity to the releasing site, Caillou Lake (Fig. 6).

In analyzing the recoveries of tagged shrimp, the opportunity was taken to plot the recoveries of the July cohort over time (Fig. 7). Two tagged animals were recovered in July , one in Caillou Lake and the other approximately off Marsh Island, Louisiana. In August the July cohort recoveries were distributed around Caillou Lake with a large number being recovered in the offshore waters of Vermilion Bay. In addition, two marked shrimp migrated northward farther into the estuarine system. By September, most of the July cohort recoveries occurred around 93° longitude. Two shrimp were also recovered inside Vermilion Bay and another tagged shrimp was recovered north of the estuarine system surrounding Caillou Lake. By September, the westward movement appeared to have stopped and the shrimp distributed along the Louisiana coast from Grand Isle to Sabine, Texas. In summary, the distribution of recoveries suggests a rapid movement out of the estuarine complex with some movement westward in August and considerable movement to the west in September. Thereafter, the tagged population appeared to remain more or less stationary. Movement patterns of small shrimp suggest for the first time that shrimp leave estuaries and migrate into other estuarine systems.

The growth patterns from the recaptured shrimp are presently being analyzed and a growth model is being constructed for each of the cohorts in this study. The growth of the four monthly cohorts along with an approximate fit of a growth curve to the points has been plotted. Fig. 8-12 depict growth of the individual cohorts. These figures clearly indicate that growth was very rapid in July, almost as rapid in August, decreasing in September and very

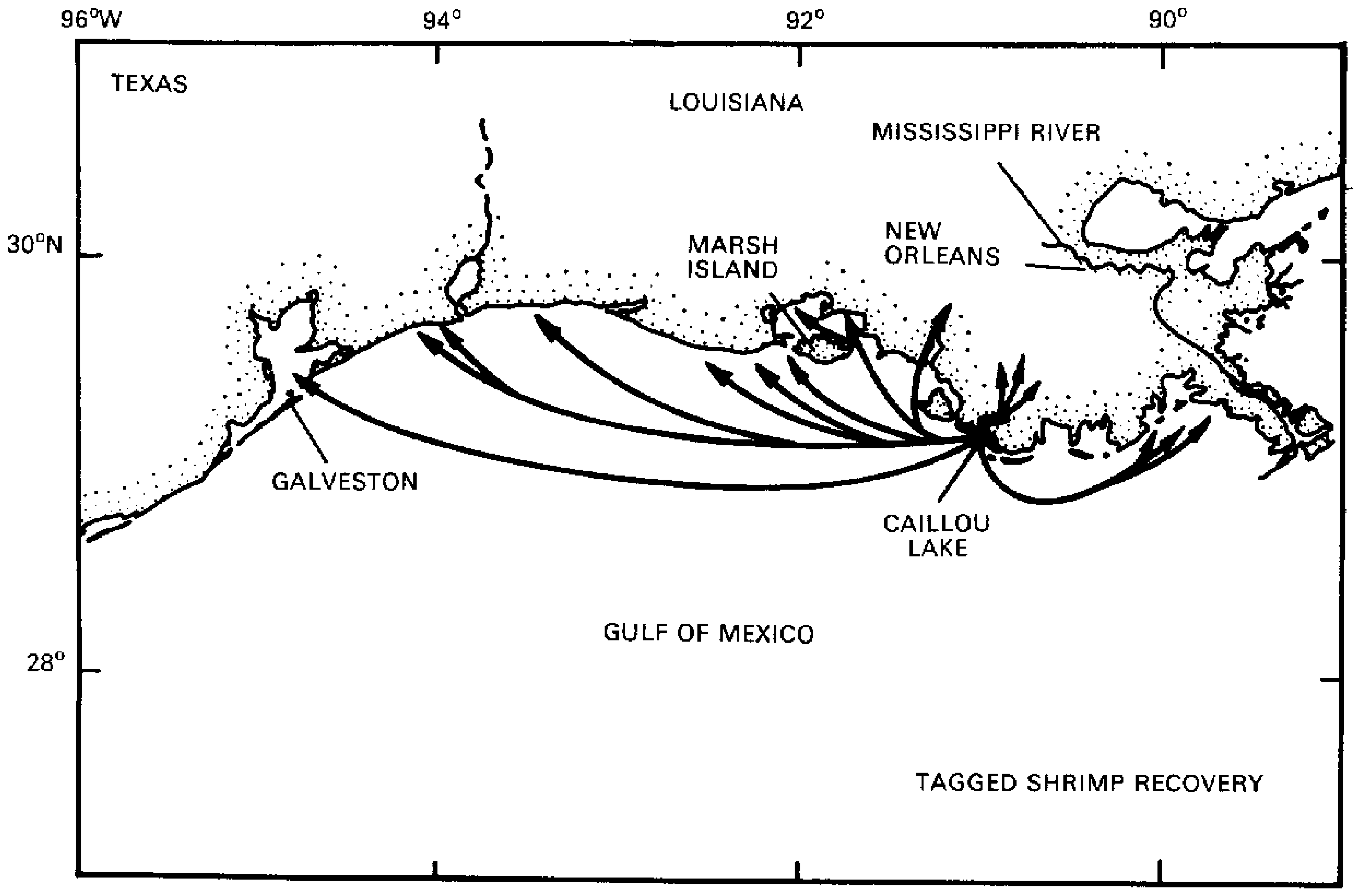

Fig. 5. General movement patterns of white shrimp released at Caillou Lake from July to October 1977.

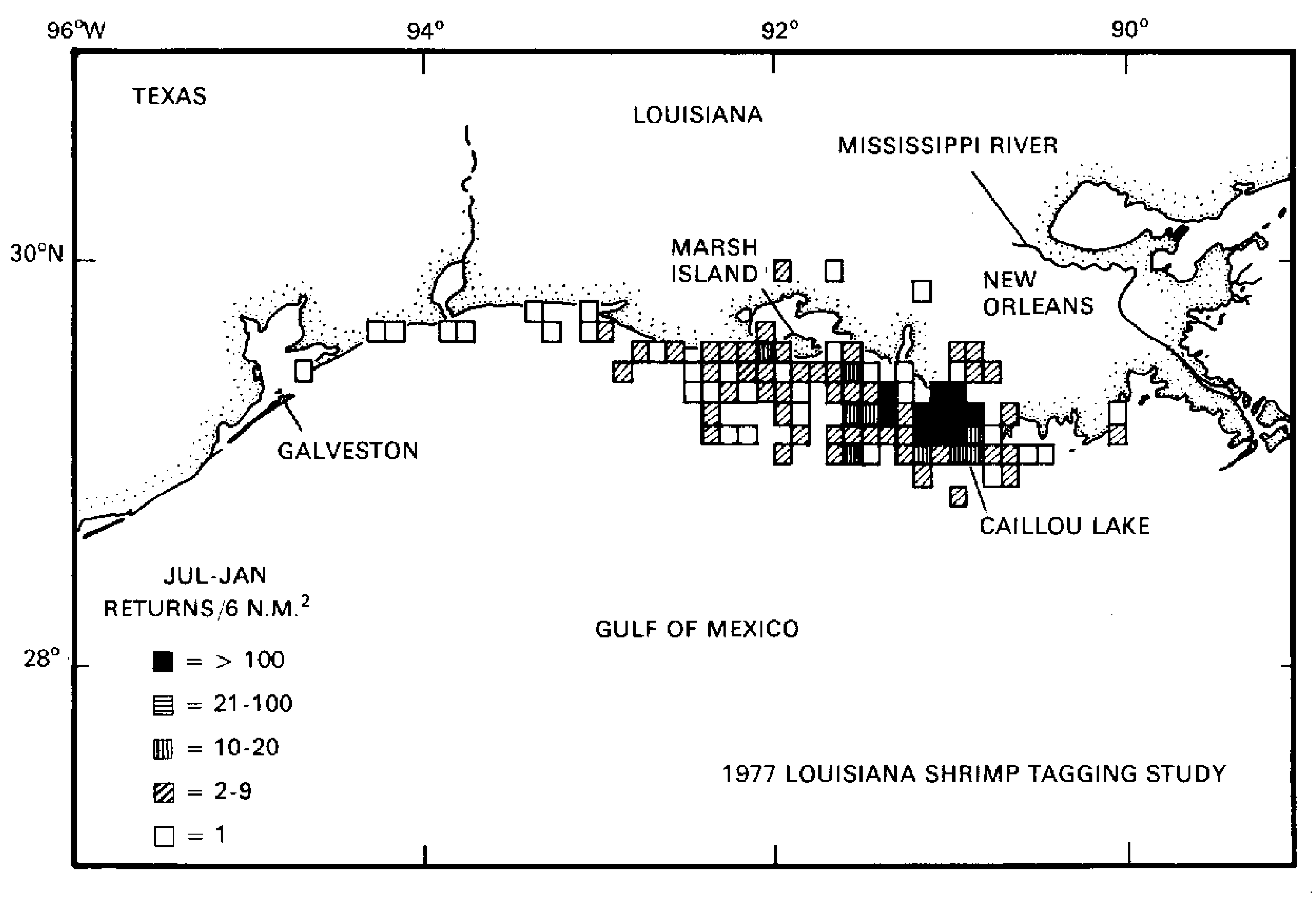

Fig. 6. Density distribution of white shrimp recoveries by six nautical square miles ($\sim$ 20.6 km^2) from July through January 1978.

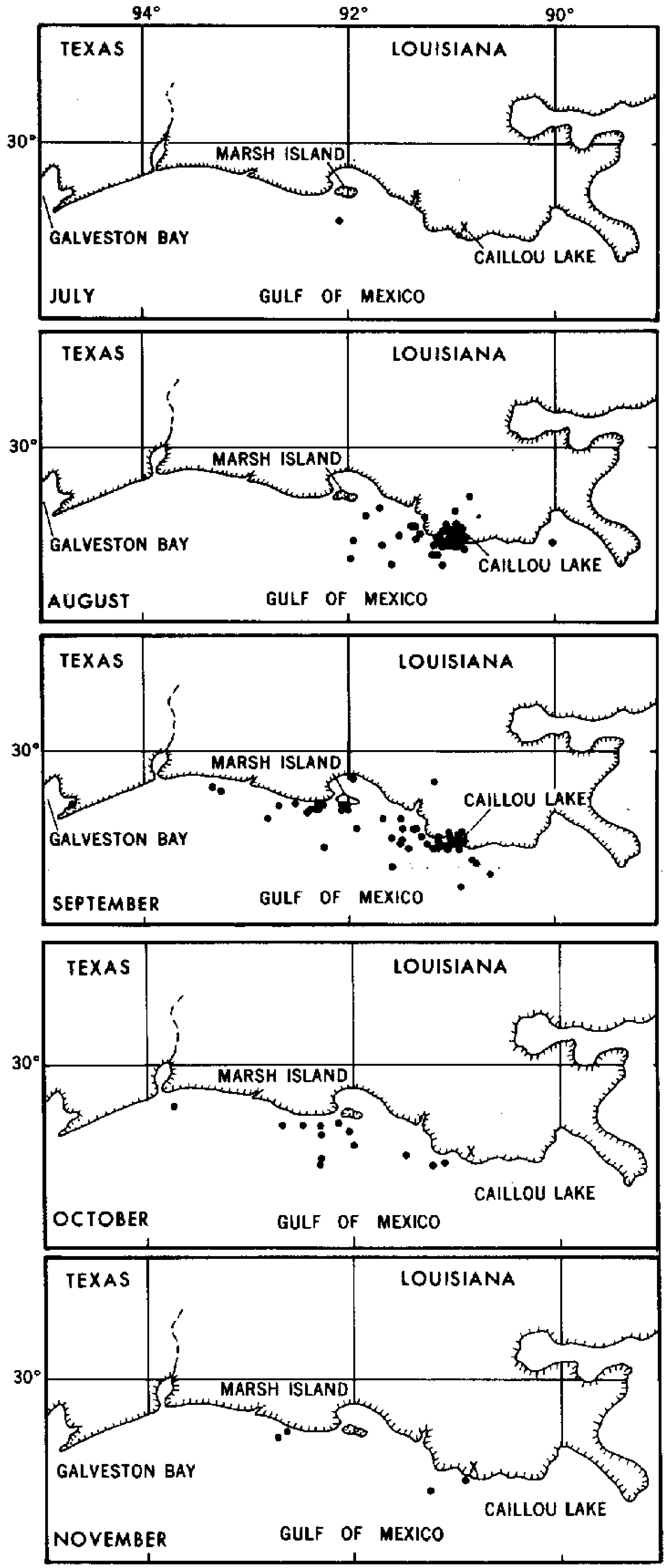

Fig. 7. Distribution of the July cohort by months.

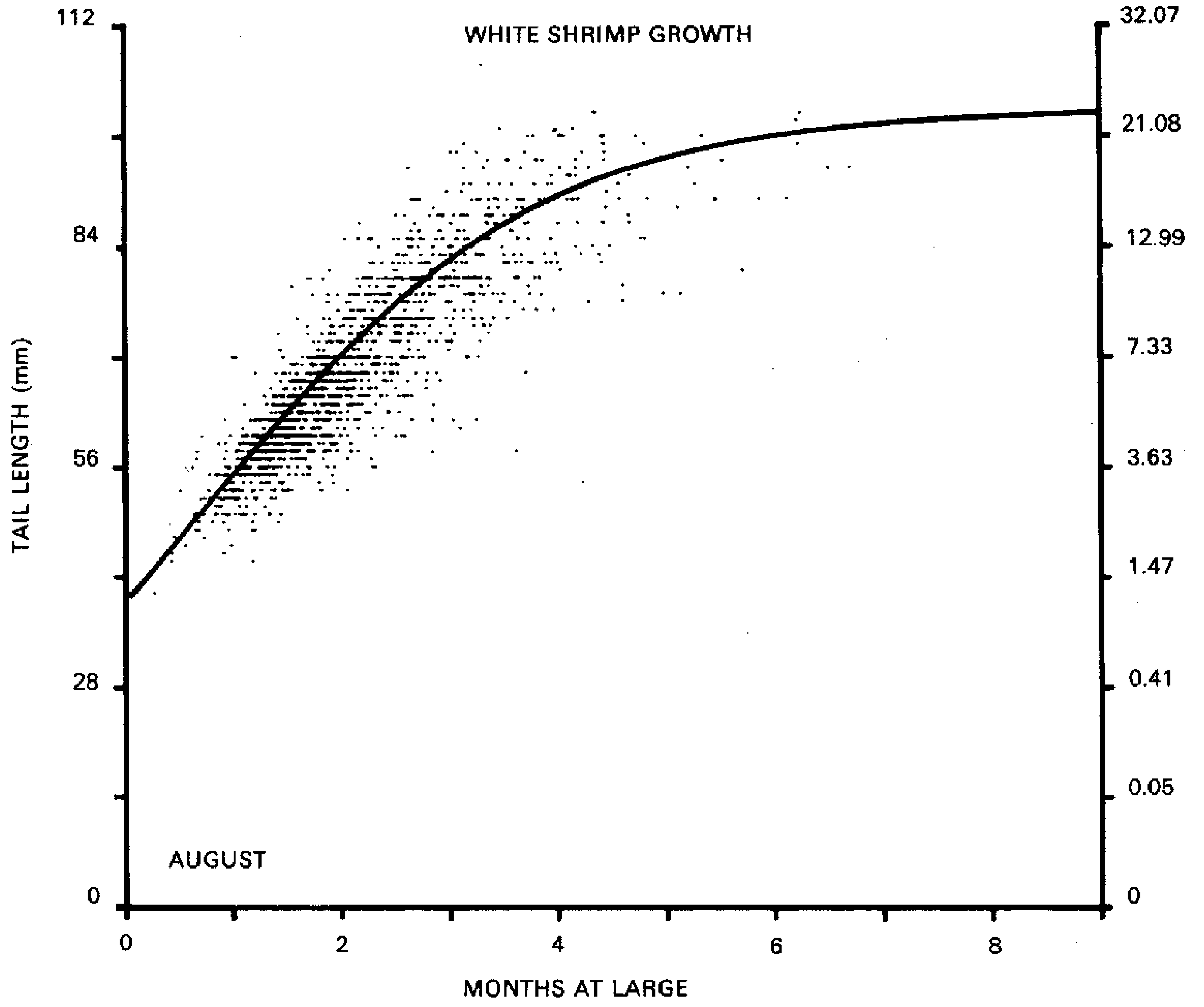

Fig. 8. Growth of the July white shrimp cohort.

slow in October. A comparison of all four lines indicates that the growth is different for the monthly cohorts (Fig. 12). Probably the main reason for the change in growth rate is that water temperatures are high in July and decrease thereafter, thus reducing the growth rate. Phares (1978) has developed a temperature dependent asymptotic growth model for white shrimp that accounts for 81 % of the variation between release size (length) and recapture size. Time dependent asymptotic growth models using the same data set accounted for about 70% of the variation. She concluded that linear growth models were inadequate and that the three asymptotic growth equations (i.e. Richards, Logistic and von Bertalanffy) fit the data almost equally well.

In addition to examining the growth patterns in more detail, the Galveston staff will be estimating mortality rates of white shrimp.

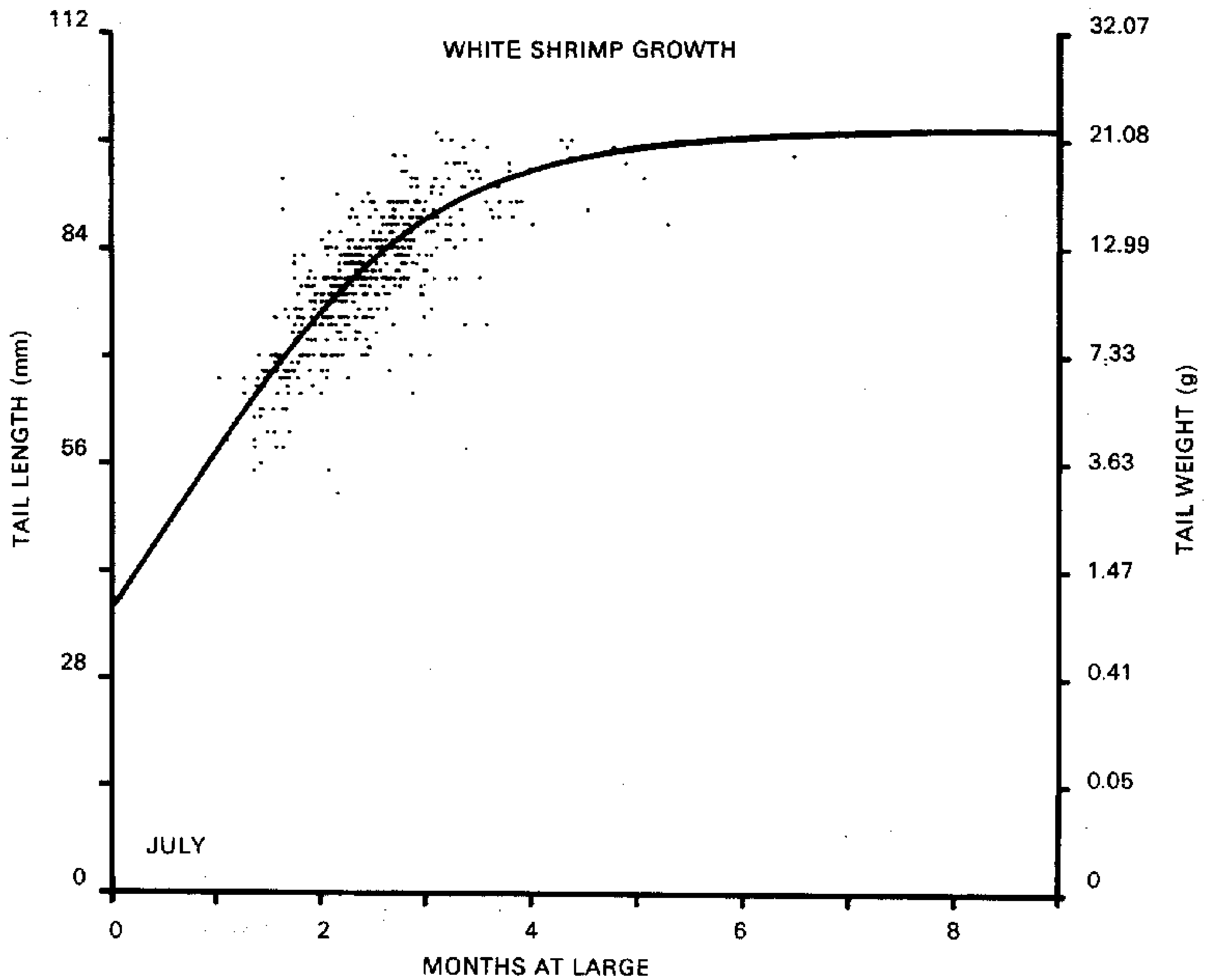

Fig. 9. Growth of the August white shrimp cohort.

Brown shrimp

During the spring of 1978, the Galveston Laboratory in cooperation with the Louisiana Department of Fisheries and Wildlife, the Texas Parks and Wildlife and the Institute Nacional de Pesca of Mexico, initiated a major brown shrimp mark-recapture experiment. The objectives of this experiment were similar to those described previously, namely to obtain estimates of growth, mortality and migration of the brown shrimp stocks in the Gulf of Mexico. A further objective was to delineate the stock boundaries of the brown shrimp resources which occur from Corpus Christi, Texas to Tampico, Mexico. Tagging was initiated in May in Caillou Lake, Louisiana and Port Mansfield, Texas (Fig. 13). To date 81,182 tagged shrimp were released in inshore areas and 26,877 were released in the offshore areas. In September a United States research vessel, Oregon II, participated with Mexico in a major mark and recapture cruise off the Mexican coast. During that month, 9,000 tagged shrimp were released from Brownsville, Texas to Tampico, Mexico.

Location and movement patterns of recoveries during the spring and summer months are depicted in Fig. 14. The releases off Louisiana indicate a movement to the east and westward

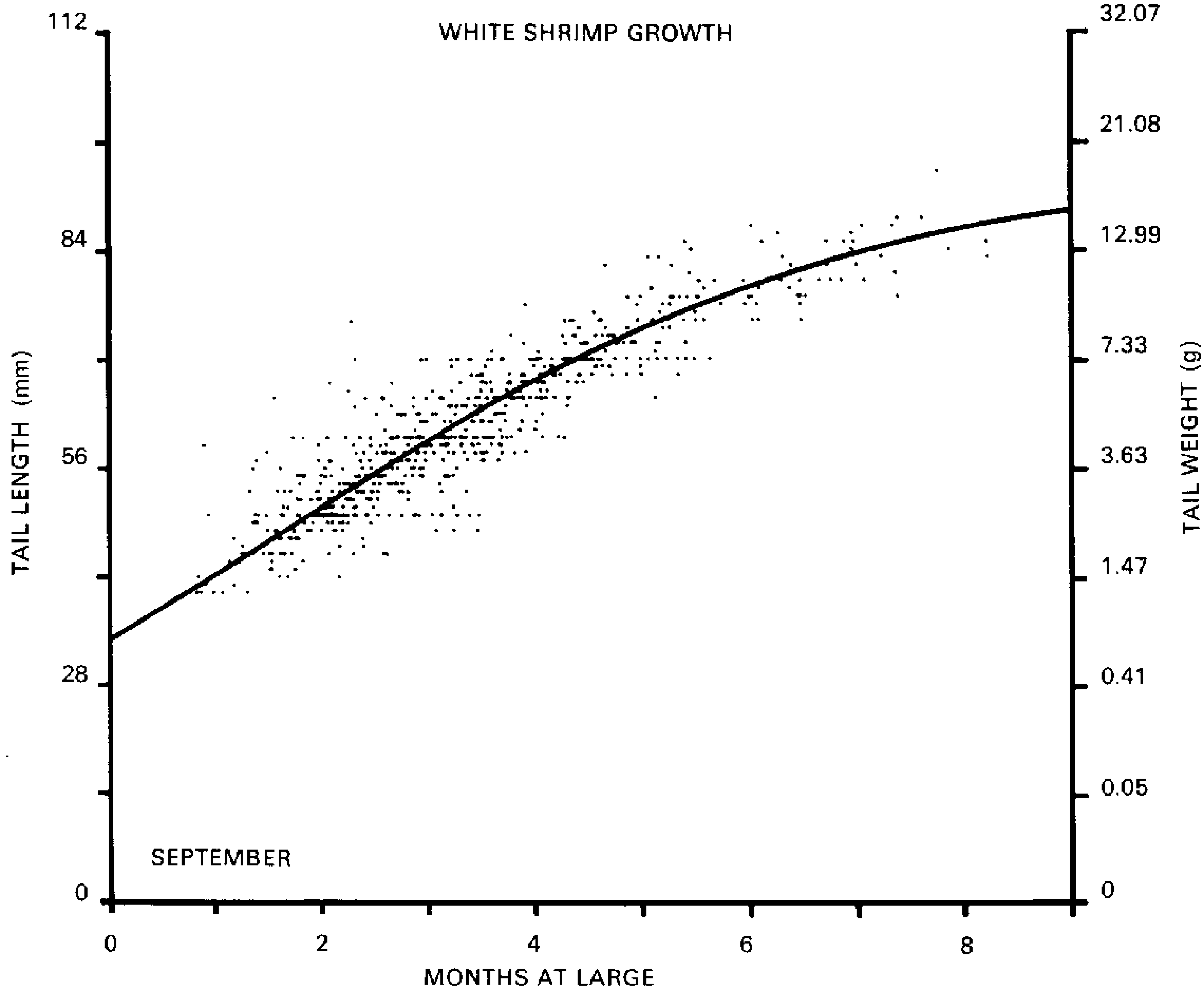

Fig. 10. Growth of the September white shrimp cohort.

from both offshore release sites. Patterns of recaptured shrimp released around Caillou Lake clearly indicate movement along shore across Vermilion Bay to the west and some eastward movement. Texas recoveries to date have been few but these indicate a coastal movement both to the south along the United States coast towards Mexico and some movement northward towards Galveston. Table 2 provides a summary of the number of releases and recoveries as of October 30 1978. It is anticipated that more tagged brown shrimp will be recovered throughout 1979.

Other inputs to management

Fishery management involves two basic decisions: first, to determine the optimum resource yield, and secondly, to allocate this yield among the various user groups. This entails decisions and regulations which affect how and to what degree the resource is used Contrary to practices in the past, when the objective of management was frequently to achieve a harvest of fish at the maximum sustainable yield (MSY), United States fishery management will, in the future, fix the quantity that can be taken rationally on the concept of

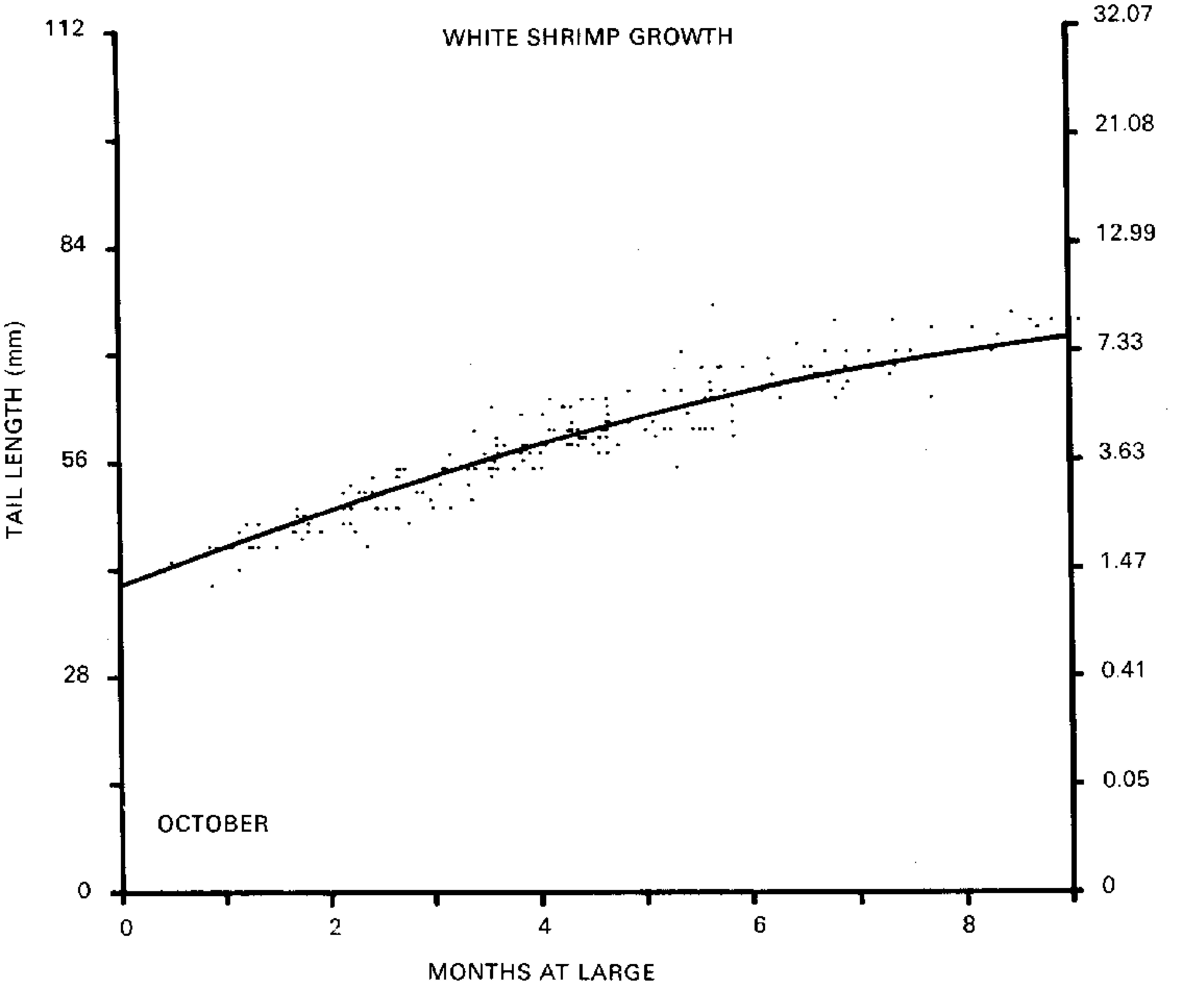

Fig. 11. Growth of the October white shrimp cohort.

Table 2. *Number of tagged brown shrimp released in the Gulf of Mexico from May through September 1978 and number and percentage recovered through October 1978.*

Location	No. released	Recovered	
		No.	%
Inshore			
Texas	42,096	6	-
Louisiana	39,086	3,963	10.1
Offshore			
Texas	4,331	170	3.9
Louisiana	13,524	428	3.2
Mexico	9,022	1,052	11.7
Total	108,059	5,619	5.2

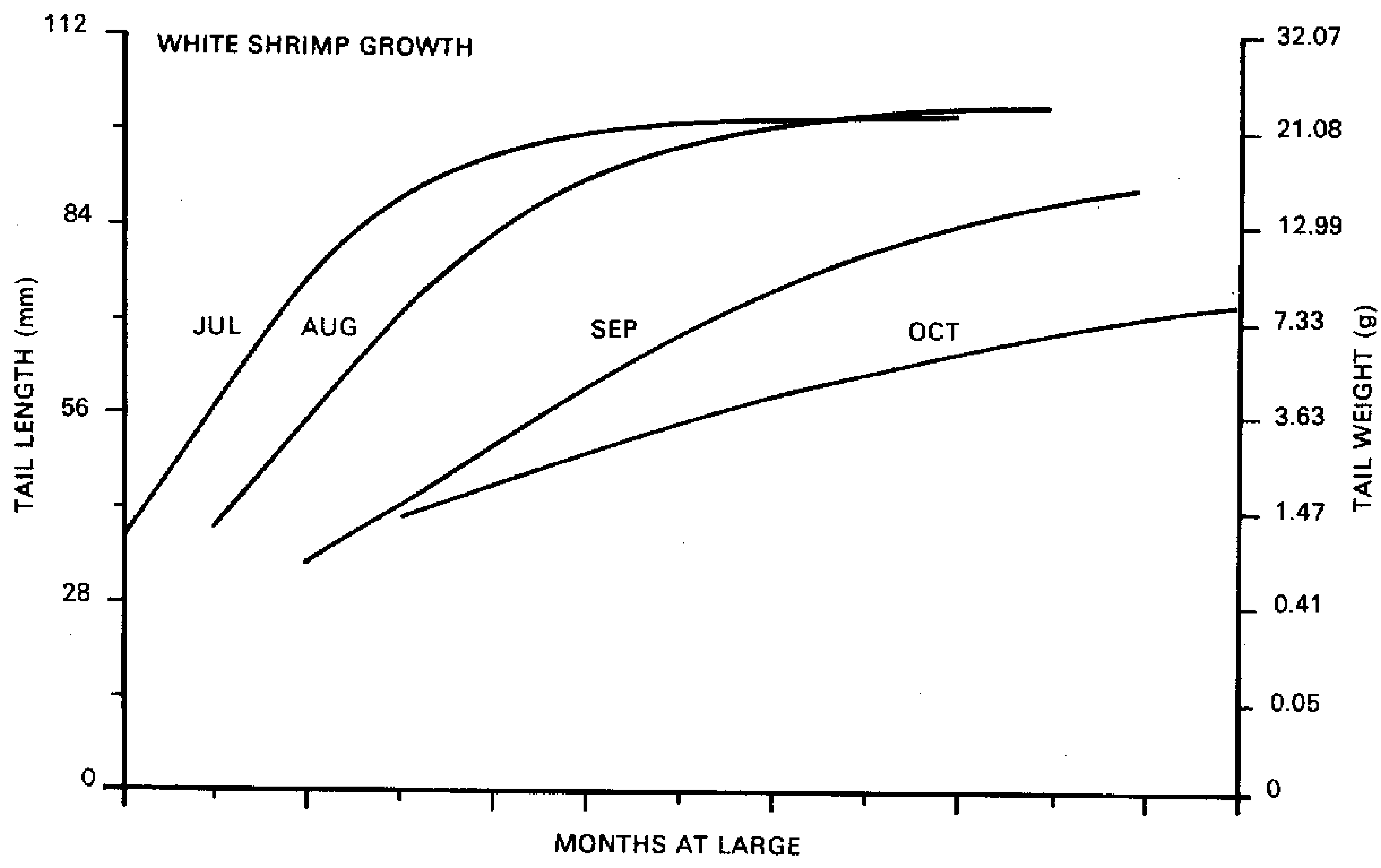

Fig. 12. Comparison of growth curves between July, August, September and October white shrimp cohorts.

optimum yield. Recently, Roedel (1975) defined optimum yield as a deliberate melding of biological, economic, social and political values designed to produce the maximum benefits to society from a given stock of fish. This means that the desires of all of the users of a resource will be considered in determining the allowable catch. This is different from the full utilization of maximum sustainable yield concept, where the commercial potential is the consideration in the harvest of the annual surplus. The concept of optimum yield put forward by Roedel is stated in broad terms and several attempts have been made to develop a more operationally useful definition. In the extended jurisdiction legislation, optimum yield is defined as a yield which provides the greatest benefit to the United States as determined on the basis of maximum sustainable yield of a stock or stocks of fish as modified by relevant ecological, economic and social factors. Another proposal would define optimum yield as the maximum sustainable yield modified by an explicit amount for a specific purpose. In both of these refinements, an attempt has been made to base the yield on a biologically determined value, MSY, and to depart from this value in such a manner that the subjective decisions implicit in including socio-economic factors are clearly spelled out so that their rationale can be fully debated.

To develop information for the optimum yield concept, we have initiated social and economic research related to the shrimp fishery in three parishes in Louisiana. In 1978, we have initiated a contract with Louisiana State University to develop cost and earnings data from commercial and recreational shrimp harvesters. On the social side, Louisiana State University will be developing data on ethnic backgrounds; attitudes towards fishing, family and social links, and the financial well-being of shrimp fishermen. It is hoped to expand these studies to other Gulf Coast states in the near future.

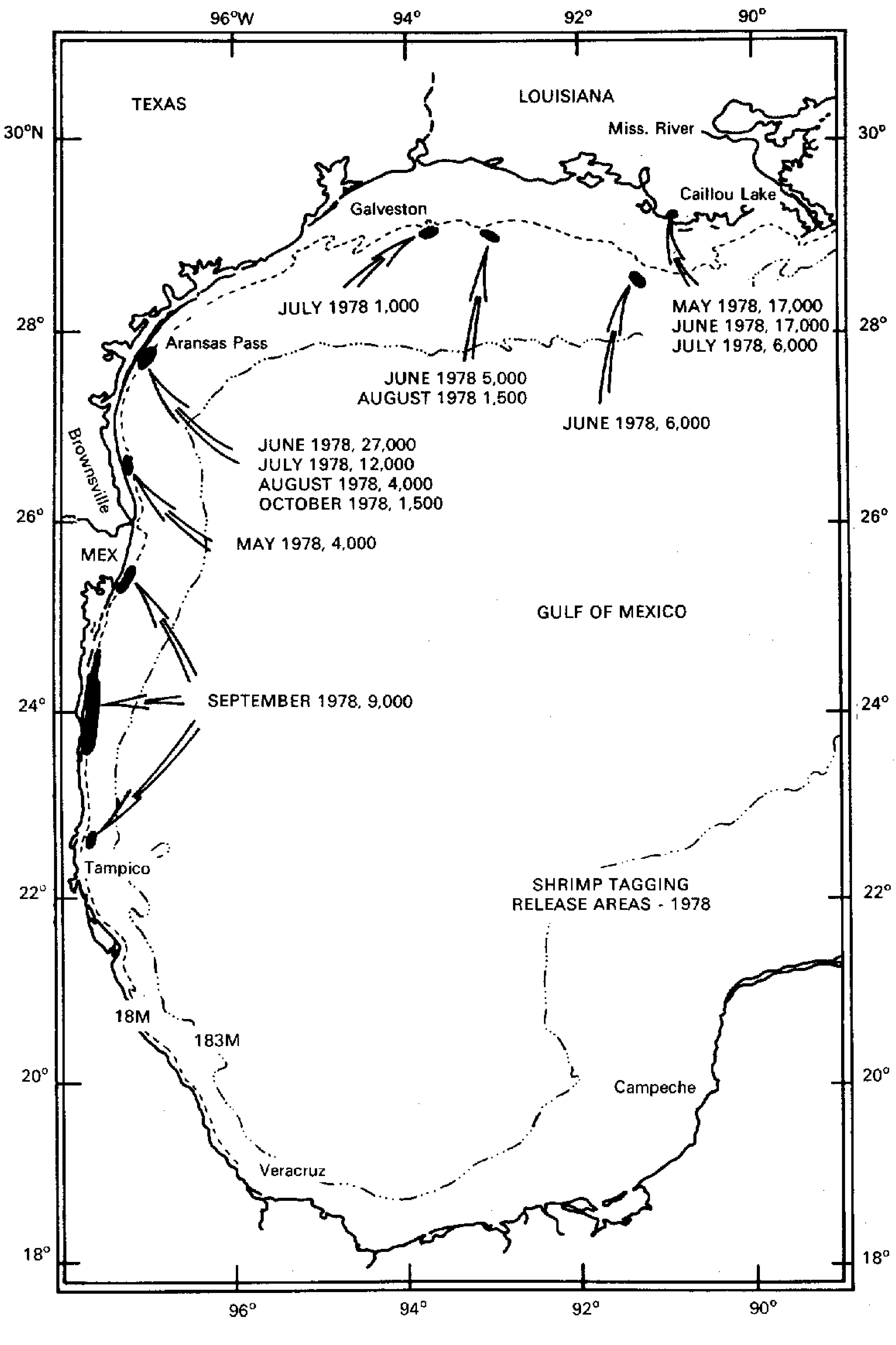

Fig. 13. Location and number of tagged brown shrimp released in 1978 in the Gulf of Mexico.

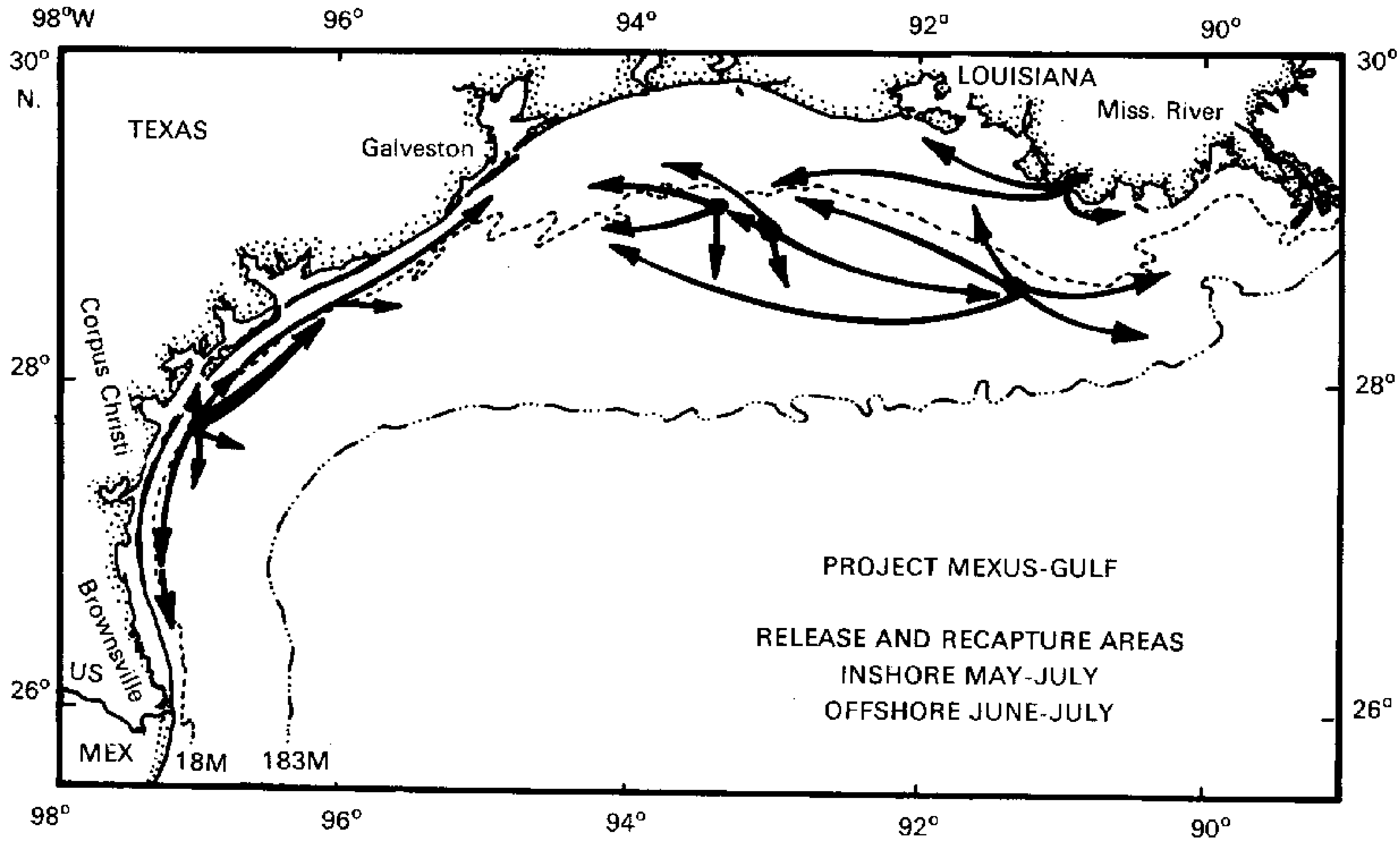

Fig. 14. General movement patterns of brown shrimp released in 1978.

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GENERAL DISCUSSION

Mathews: You speak of a typical cohort in September?

Klima: We tag large numbers of shrimp over several months: those tagged in a given month are arbitrarily assigned to that month's cohort. Because of the geographical range of shrimp, from estuaries to offshore and because the commercial boats cover most of this, we assume that all released shrimp have an equal chance of being recovered.

Mathews: Do they spawn in the estuaries?

Klima: They spawn offshore. The post-larval shrimp enter the estuaries in waves.

Mathews: Are there several cohorts per year?

Klima: Yes, for brown shrimp *(Penaeus aztecus)* we recognise three to five cohorts during the season.

Mathews: Are size distributions available? I ask this because many papers base growth estimates on size frequency distributions, and may show, say four cohorts, but on closer examination one might say that there were two or maybe only one cohort in fact.

Klima: Yes; it is difficult to be sure but at times you can distinguish them pretty easily.

Kurata: What is the major advantage of your streamer tags?

Klima: You can tag more shrimp with streamer tags than you can using Petersen tags in a given time and at a smaller size (50 mm total length). Previously people had used Petersen discs, starting with big discs and then using smaller discs, but we feel that even small Petersen discs cause a bias.

Farmer: Did the tags you were using have rounded or tapered ends?

Klima: All brown shrimps and most of the white shrimp *(Penaeus setiferus)* were tagged using those with tapered ends. When working we tag everything we can lay our hands on and nothing is left. It is an expensive proposition in terms of 12 people working for 10 days.

Al-Attar: Apart from your intensified tagging programme, do you have any other type of management work?

Klima: Besides the shrimp tagging programme, we also obtain information on the economics of the fishery. We have a contract to look at the basic social and economic characterisitics of the shrimp fishery in Louisiana and we expect this contract will be expanded. In addition to the shrimp tagging programme we have been collecting catch and effort data for many years throughout the Gulf of Mexico. We are also looking at the size distribution of all commercial fisheries and are taking the commercial catch and applying growth functions to commercial catches and local catch curves to obtain mortality from this. However dependence of the growth rate on temperature confuses the picture very much at least for white shrimps. If we try to identify how old the animal is by its size, we have to know the temperature regime to which it was subject during the earlier part of its life. This is very much more complicated than we had presumed. This is one reason why we establish cohorts on a monthly basis; although this is arbitrary it tends to separate shrimp subjected to different temperature regimes.

Farmer: You said that you are three years behind in the catch/effort data.

Klima: We are three years behind because we are changing the system and there are bureaucratic problems.

Farmer: Therefore in three years time you may be getting other evidence which you can contrast with the results from your tagging programme.

Al-Attar: Do you release your shrimps in the place where you capture them or move away from that place and then release them?

Klima: In a practical sense we cannot release exactly where we capture them because we are trawling, and moving continuously. We are working for 12 hours per day. However you should release away from the commercial fleet because they may know what we are doing.

Al-Attar: What is the relationship between the currents and the shrimp movements?

Klima: Basically there is a west bound current in the summer months in Louisiana and Texas which gives rise to what I call directed migration or directed movement of the shrimp. One of the problems in tagging is that you know where you have released the shrimp and where you have picked it up but you do not know what it did in between. I suspect that there is a coastal current and the true movements of shrimp may be very much more complex, than presently seems to be the case.